To: David Starr, NASA Goddard Space Flight Center, Greenbelt MD 20771

Date: August 15, 2001

RE: Earth Observing System Validation Project Accomplishments FY 2001

Project: Application of Saudi Arabian Surface Radiation Flux Measurements for Validation of Satellite Remote Sensing Systems

Co-Principal Investigators: Daryl R. Myers, National Renewable Energy Laboratory (NREL) 1617 Cole Blvd MS 3411 Golden, CO 80401 (daryl_myers@nrel.gov)
Dr. Naif Al-Abbadi King Abdulaziz City for Science and Technology (KACST) Energy Research Institute PO Box 6086 Riyadh 11442 Kingdom of Saudi Arabia (Nabbadi@kacst.edu.sa)

Introduction

This project provides Earth Observing System (EOS) Terra satellite instrumentation and science teams with surface radiometric flux data to assist in estimating the uncertainty in and validate Terra data products. The King Abdulaziz City for Science and Technology (KACST) Energy Research Institute operates a twelve-station solar radiometric network distributed on about a five degree by five-degree latitude/longitude grid over the Kingdom of Saudi Arabia. The National Renewable Energy Laboratory (NREL) Center for Renewable Energy Resources assists KACST with the quality control and technical applications of the network data. Network data quality is assessed and flagged with respect to uncertainty and archived by KACST and NREL. Quality assessed data for all twelve stations are posted on an NREL Internet page **http://rredc.nrel.gov/solar/new_data/Saudi_Arabia/** for access by the EOS science and instrumentation teams. NREL and KACST interact with science and instrumentation teams to provide logistics for data access, quality assessment, uncertainty analysis and improvement of Saudi network instrumentation, and to support the deployment and operation of NASA owned instruments at the central KACST station located at the Solar Village 40 km northwest of Riyadh.

FY 2001 Accomplishments

NOTE

Between March of 2001 and August of 2001, there were delays in NREL/DOE processing of incremental funding allocations from Goddard Space Flight Center. No funds were available for this work from March of 2001 to August of 2001. This situation has been corrected, funds have been released, and priorities for the rest of the fiscal year 2001 are to work mainly on deliverable 4, below. A one year no-cost extension of the project until Sep 2002 has been prepared and submitted to NASA in order to meet the objectives of the statement of work.

Technical Progress

The statement of work for Fiscal Year (FY) 2001 for the project included the following deliverables:
1) Internet availability of quality assessed monthly data files for the 12 station KACST network .

2) Assist Saudi Arabia to maintain the high quality of their entire network, and the Baseline Surface Radiation Network (BSRN) Station with monthly submission of BSRN station data to the BSRN archive. Coordinate the loan of NASA equipment with KACST.

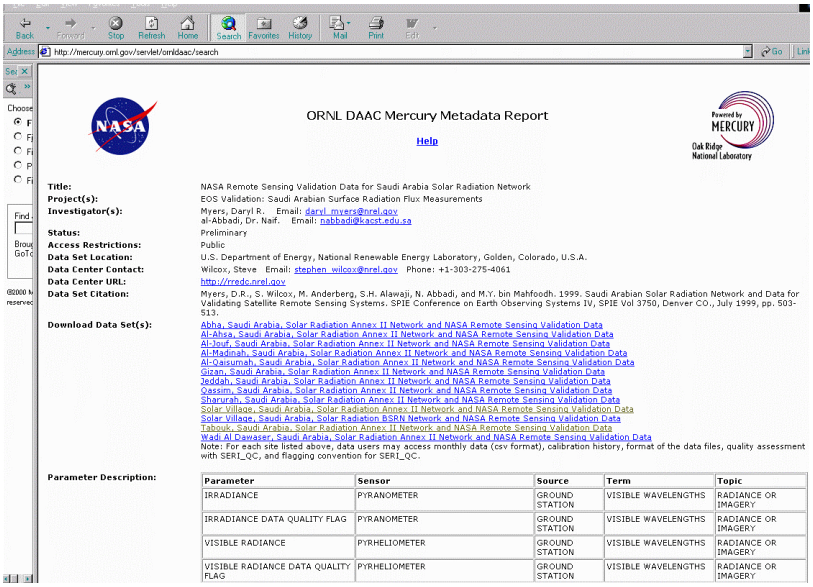
(3) Participation in workshops, meetings, and personal communications to NASA validation teams.

(4) Comparison of NREL and EOS estimates of atmospheric properties (aerosols, water vapor) developed for Saudi Arabia.

These objectives have been totally or partially addressed during FY 2001, within the funding availability noted above, as addressed below.

Quality Assessment and Internet Availability of Surface Flux Data

The data are posted on the NREL maintained website in station-month files. These files are accessible either directly through the NREL URL (**http://rredc.nrel.gov/solar/new_data/Saudi_Arabia/)**, or through the MERCURY access system maintained by Oak Ridge National Laboratory (ORNL) at http://mercury.ornl.gov/ornldaac/.



NREL has co-ordinated an upgrade to the oak Ridge National Laboratory MERCURY web crawler interface to the Saudi Arabian data posted on the NREL website. Carroll Curtis of ORNL updated the interface to make access to the data sets much easier.

Under the URL mentioned above, one selects “Data Set Titles” and then “NASA Remote Sensing Validation Data for Saudi Arabia Solar Radiation Network” and the page to left appears. Each individual station can then be accessed, and metadata and ancillary information is presented in a more compact and straightforward form.

Table 1 displays the web site activity through Fiscal year 2001, indicating a total of 31,170 page views over the nine months for which activity data is available. We do not have data on the specific identity of programs or teams accessing the data.

Table 1. NREL/NASA EOS Validation Website Activity Log, Oct 2000-Jun 2001

Month	Jun-01	May-01	Apr-01	Mar-01	Feb-01	Jan-01	Dec-00	Nov-00	Oct-00
Total Page Views	4,370	2,164	2,851	4,454	4,375	5,012	3,208	3,344	1,392

Assistance for Network and BSRN Station Quality

BSRN Station Troubleshooting

NREL wrote custom software to reformat the ASCII data files for the Solar Village BSRN site for submission to the BSRN Archive at **http://bsrn.ethz.ch/.** This reformatting software reports the monthly Solar Village BSRN data in the format prescribed by the BSRN. We developed a scheme for making the direct normal irradiance serially complete when cavity radiometer is not available for measurement. Every 4 hours, the cavity radiometer is re-calibrated, and 10 minutes of direct beam data is replaced by the pyrheliometer data. The pyrheliometer data is scaled based on a comparison between the cavity and the pyrheliometer data just before the calibration starts, and after it ends.

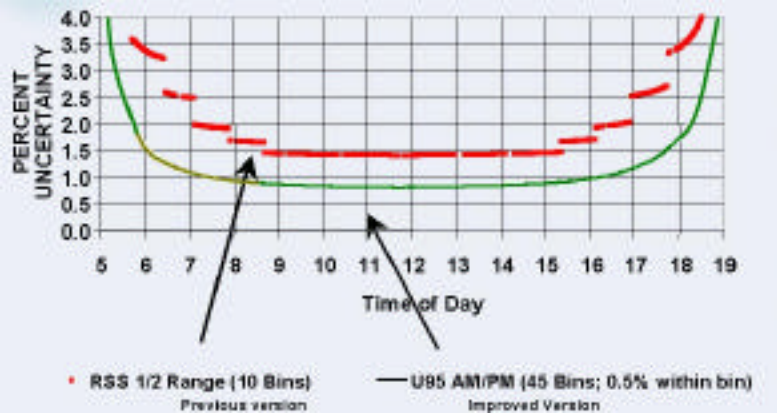
During software testing, we identified significant problems with the BSRN absolute cavity radiometer at the Solar Village site. Contacting the KACST station operators, we found that the cavity radiometer was being infiltrated by moisture, which condensed on the interior surface of the cavity window. Extensive trouble shooting took place, including return of the cavity to the Eppley Laboratory for their examination. Eppley traced te source of the moisture infiltration to a cracked connector on the automated shutter assembly of the cavity. The shutter connector was replaced, the radiometer compared to Eppley standards to assure the calibration and world radiometric reference factor had not changed, and returned to KACST.

In the meantime, NREL developed additional software to identify contaminated and incorrect absolute cavity data. We then developed an algorithm to replace the contaminated data with normal incidence pyrheliometer data when contamination appeared in the historical data.

In June, 2001, and again in August, 2001 we made our first submission of test BSRN formatted data sets to the BSRN data archive. The BSRN archive automatically examines the submissions for correct format before inserting them into the archive. If there are problems, a report file is returned to guide the site scientist in reconciling the problems. After troubleshooting, the data can be re-submitted. At the time of this report we are awaiting feedback from the BSRN archive on the status of the test data files.

Radiometer Calibration Techniques and Processing

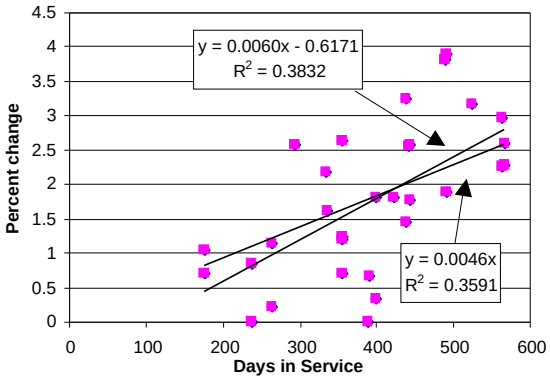
During FY 2000, NREL implemented an upgrade to the Radiometer Calibration and Characterization (RCC) hardware and software used to calibrate broadband radiometers at the KACST calibration facility at the Solar Village. Improvements included installation of an Eppley model 8-48 Black and White pyranometer for measuring the reference diffuse irradiance during calibrations, higher resolution zentih angle binning of radiometer response (forty five 2° bins, rather than the former ten 10° bins) and revised uncertainty analysis of the RCC results.



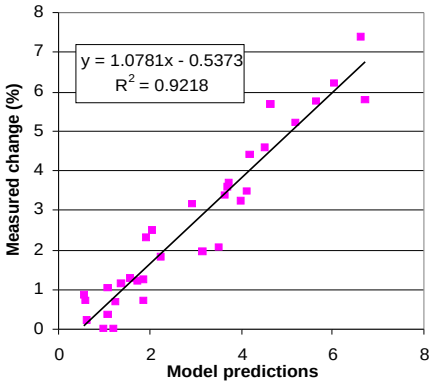
The figure shows that the uncertainty in radiometer responsivities is reduced by at least 50% using the new implementation of RCC.

A Broadband Radiometer Outdoor Calibration (BORCAL) event (2000-01) was conducted at KACST, using the new instrumentation. Results for control instruments were consistent with BORCAL events conducted in 2000. All twelve stations and the BSRN station received newly calibrated instruments for all three solar radiation components.

We investigated the degradation of broadband global pyranometer responsivities as a function of irradiance and temperature in the Saudi environment. The figures below show our multiple regression model predicts radiometer degradation with much greater confidence than just a model based on exposure duration.



Degradation as a function of deployment time.



Multiple regression model predictions for radiometer calibration drift as function of irradiance and temperature

These results are documented in the citations in the publications section below.

CIMEL Sunphotometer Operational Assistance

In November, 2000, NREL assisted with the exchange of the CIMEL sunphotometer installed at the Solar Village site with a newly calibrated unit. In January and May, 2001, NREL assisted KACST and the NASA Aeronet activity to troubleshoot problems with the time stamp on CIMEL data and a new battery for the sunphotometer, respectively.

Workshop Participation

On Jan 14, 2001 members of the NREL team attended training on the use of tools to search and order EOS and related data held in the EOSDIS archives, and to visualize and manipulate HDF-EOS data, in Albuquerque, New Mexico. This training allows NREL to acquire and use various Terra EOS data products for comparison with NREL /KACST data products.

Water Vapor and Aerosol Optical Depth Analysis

We obtained training to access EOS data sets through the EOS Data and Information System (EOSDIS) and have downloaded a few selected data sets. However, the funding limitations mentioned in the note above precluded work in this area. This objective is the primary focus of the work for the remaining two months of FY 2001.

Publications

Myers, D.R., T.L Stoffel, S. Wilcox, I. Reda, A. Andreas., "Recent Progress in Reducing the Uncertainty in and Improving Pyranometer Calibrations" Submitted to *ASME Journal Solar Engineering*, Nov 2000

Reda, I., J.R. Hickey, T. Stoffel, D. Myers, "Pyrgeometer Calibration at the National Renewable Energy Laboratory (NREL)" Submitted to Journal of Atmospheric and Solar Terrestrial Physics, April 2001.

Wilcox, S., N. Al-Abaddi, D. Myers, M. bin Mahfoodh, "Improving Global Solar Radiation Measurements Using Zenith Angle Dependent Calibration Factors" Proceedings of the American Solar energy Society Annual Meeting, Forum 2001, April 21-25, 2001, Washington, D.C. R. Campbell-Howe, ed.

Wilcox, S., N. Al-Abaddi, D. Myers, M. bin Mahfoodh "Using Irradiance and Temperature to Determine the need for Radiometer Calibrations" Proceedings of the American Solar energy Society Annual Meeting, Forum 2001, Washington, D.C. April 21-25, 2001, R. Campbell-Howe, ed.

Abbadi, N.M., S.H. Alaawaji, M.Y. bin Mahfoodh, D.R. Myers, S. Wilcox, M. Anderberg, "Saudi Arabian Solar Radiation Network Operation Data Collection and Quality Assessment" Renewable Energy, Vol 25 #2, Feb 2001.

Conclusion

Radiometer calibration and characterization upgrades reducing uncertainty have been developed and documented. Redesign of the NREL Saudi data web site is complete, and access through the ORNL Mercury web crawler has been greatly simplified. Corrections to global horizontal pyranometer data, and computed global horizontal data have been retroactively, and currently, incorporated into the data. The effect of temperature and irradiance exposure on pyranometers in the Saudi environment has been evaluated. Test data sets have been submitted to the BSRN archive for evaluation. Routine submissions to the BSRN archive should occur in the Fall of 2001. The NREL team will utilize NASA GSFC training in HDF-EOS data manipulation to compare NREL and Terra/EOS data products. The fundamental uncertainty in the Saudi network fluxes has been established at ±8 W/m_ for clear skies, and ±6.6 W/m_ for cloudy conditions. (See previous progress report for FY 2000).